

PRE-NEOGENE TECTONIC DIVISIONS AND MIDDLE PERMIAN BRACHIOPOD FAUNAL PROVINCES OF JAPAN

J. TAZAWA

Department of Geology, Faculty of Science, Niigata University, Niigata 950-2181, Japan

TAZAWA, J., 1998:11:30. Pre-Neogene tectonic divisions and Middle Permian brachiopod faunal provinces of Japan. *Proceedings of the Royal Society of Victoria* 110(1/2): 281–288. ISSN 0035-9211.

Middle Permian brachiopod faunas of Japan are classified into two types, the Boreal–Tethyan mixed fauna of the Inner Mongolian–Japanese Transition Zone and the Tethyan–North American mixed fauna of the Tropical Panthalassan Zone. The former occurs from pre-Triassic accretionary terranes, the South Kitakami Terrane and the Akiyoshi Terrane, which were probably a continental shelf and a trench along the eastern margin of the Sino-Korean block, respectively, in the Middle Permian time. The latter occurs from exotic limestone blocks in the Mino Terrane, an Early Jurassic to Early Cretaceous accretionary terrane. These limestone blocks were probably parts of reef–seamount complexes situated at the mid-equatorial region of the Panthalassa in the Middle Permian time.

DURING the last decade the Permian biogeography of the world has been discussed by many authors (Chaloner & Creber 1988; Xu & Yang 1988, 1994; Bambach 1990; Ross & Ross 1990; Ziegler 1990; Grunt 1995; Shi et al. 1995; Grunt & Shi 1997; Shang & Jin 1997; Jin & Shang 1997). The Permian brachiopod faunas of Japan are important for geographical and biogeographical reconstruction of the Northern Hemisphere in that time. In this paper the generic composition and character of the Japanese Middle Permian brachiopod faunas are summarised, and their faunal provincialism is discussed in connection with pre-Neogene tectonic divisions of the Japanese Islands.

PRE-NEOGENE TECTONIC DIVISIONS OF THE JAPANESE ISLANDS

The pre-Neogene rocks of the Japanese Islands are classified into the following nine terranes (Tazawa 1993): Hida Terrane (the oldest terrane containing Precambrian rocks but lacking the Permian), South Kitakami Terrane (Middle Ordovician to Early Devonian accretionary terrane with Permian continental shelf deposits), Akiyoshi, Suo, Maizuru and Ultra-Tanba Terranes (Middle to Late Permian accretionary terranes with trench-fill deposits of the same age; only the Akiyoshi Terrane contains exclusively Early Carboniferous to Middle Permian exotic limestone blocks), Mino and Sanbagawa Terranes (Early Jurassic to Early Cretaceous accretionary terranes with Permian exotic limestone

blocks) and Shimanto Terrane (Late Cretaceous to the earliest Neogene accretionary terrane without the Permian). These terranes are arranged in the NE–SW direction, subparallel to the extension of the Japanese Islands, and younging towards SE, from the Japan Sea side to the Pacific side (Fig. 1).

The geotectonic framework of the Japanese Islands was formed through long-term subduction along the Sino-Korean block since Middle Ordovician (Tazawa 1993). The east- or southward thrust movement occurred and formed several nappes and klippe, such as the Hida Nappe (Komatsu et al. 1985), South Kitakami Nappe (Tazawa 1988) and Kurosegawa Klippe (Isozaki & Itaya 1991) in the latest Jurassic to earliest Cretaceous time. The large scale left-lateral strike-slip motion occurred along the Tanakura Tectonic Line (TTL) and the Median Tectonic Line (MTL) in the Early Cretaceous to Palaeogene time (Taira et al. 1989; Tazawa 1993). And finally, the opening of the Japan Sea caused clockwise rotation of Southwest Japan and counterclockwise rotation of Northeast Japan in the Early Neogene time (Otofujii & Matsuda 1983; Otofujii et al. 1985).

MIDDLE PERMIAN BRACHIOPOD FAUNAS OF JAPAN

The Middle Permian (Artinskian–Capitanian) brachiopod faunas of Japan are divided into two types, the Boreal–Tethyan mixed fauna and the Tethyan–

North American mixed fauna. As shown on Fig. 1 and Table 1, the Boreal-Tethyan mixed fauna is represented by those of the South Kitakami Terrane (South Kitakami Belt and Hida Gaien Belt) and the Akiyoshi Terrane (Akiyoshi Belt), and it contains both the Boreal and Tethyan elements. The Tethyan-North American mixed fauna is

represented by those of the Mino Terrane (Ashio Belt and Mino Belt), and it contains both the Tethyan and North American elements.

Boreal-Tethyan mixed fauna

South Kitakami Terrane. In the South Kitakami

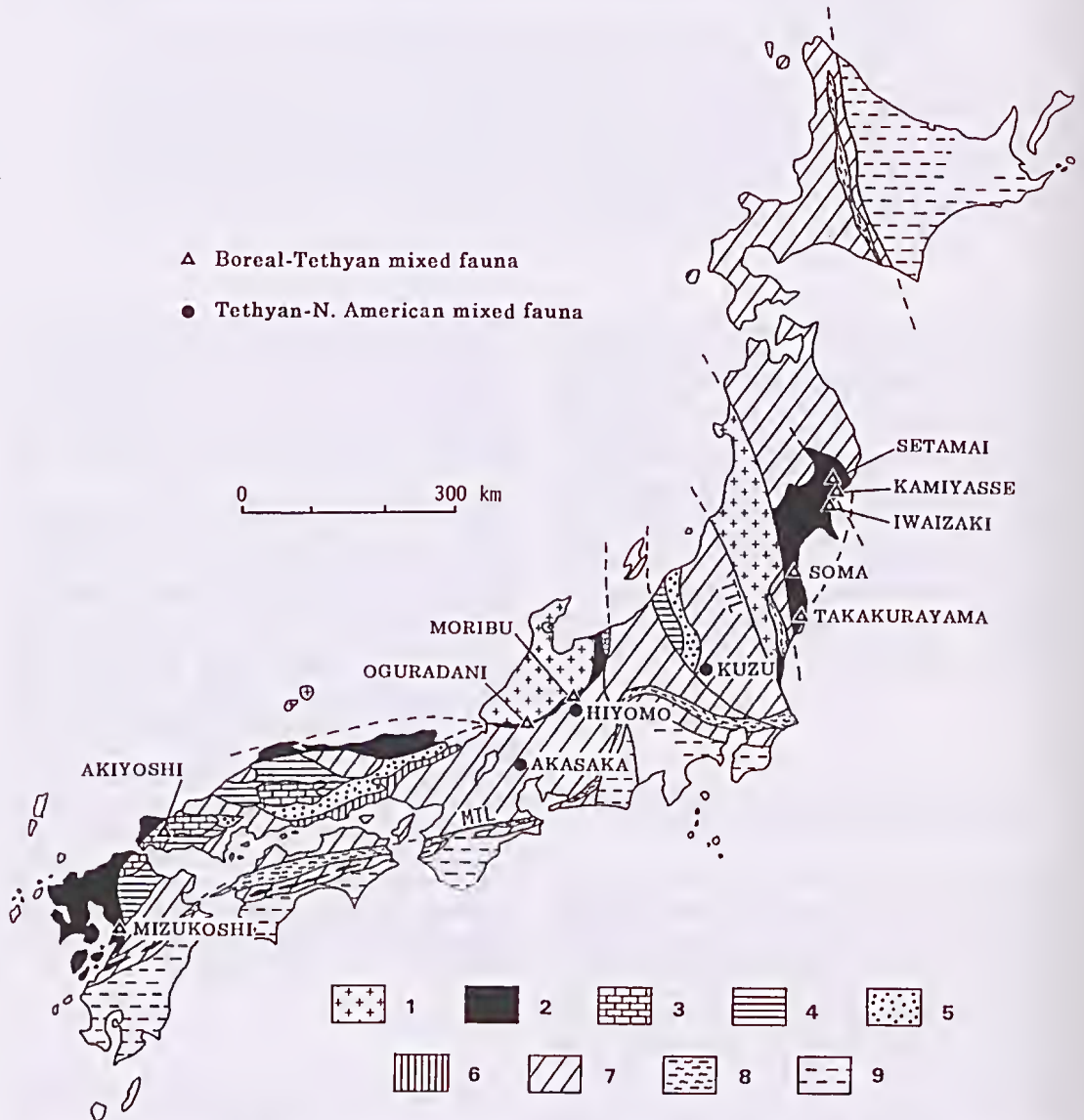


Fig. 1. Distribution of Middle Permian brachiopod faunas and pre-Neogene terranes in Japan (adapted from Tazawa 1993). TTL, Tanakura Tectonic Line; MTL, Median Tectonic Line; 1, Hida Terrane; 2, South Kitakami Terrane; 3, Akiyoshi Terrane; 4, Suo Terrane; 5, Maizuru Terrane; 6, Ultra-Tanba Terrane; 7, Mino Terrane; 8, Sanbagawa Terrane; 9, Shimanto Terrane.

| Brachiopoda fauna [Faunal province] | Terrane [Belt] | Middle Permian reconstruction |
|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------|
| I Boreal-Tethyan mixed fauna [Inner Mongolian-Japanese Transition Zone] | Middle Ordovician-Early Devonian accretionary terrane South Kitakami Terrane [South Kitakami Belt] [Hida Gaien Belt] | Continental shelf on the eastern margin of the Sino-Korea |
| | Middle-Late Permian accretionary terrane Akiyoshi Terrane [Akiyoshi Belt] | Trench along the eastern margin of the Sino-Korea |
| II Tethyan-North American mixed fauna [Tropical Panthalassan Zone] | Early Jurassic-Early Cretaceous accretionary terrane Mino Terrane [Mino Belt] [Ashio Belt] | Reef-seamount complex on the mid-equatorial region of the Panthalassa |

Table 1. The characters, faunal provinces, localities and their reconstruction of the Japanese Middle Permian brachiopod faunas.

Belt, Northeast Japan, the Middle Permian brachiopod faunas have been known from the Kanokura Formation of Setamai, Kamiyasse and Iwaizaki districts in the southern Kitakami Mountains (Hayasaka 1922, 1925, 1960; Hayasaka & Minato 1956; Mabuti 1935; Nakamura 1959, 1960, 1970, 1972a, 1979; Tazawa 1974, 1976, 1979, 1987b; Tazawa & Araki 1984; Minato et al. 1979; Shen & Tazawa 1997), the Oashi Formation of the Soma district (Tazawa & Gunji 1982) and the Takakurayama Formation of the Takakurayama district (Yanagisawa 1967; Nakamura 1972b; Koizumi 1979) in the Abukuma Mountains. These faunas are characterised by the presence of both the Boreal and Tethyan elements. The Boreal-type representatives are *Yakovlevia*, *Canocrinella*, *Waagenoconcha*, *Megousia*, *Stenosisma*, *Spiriferella* and *Neospirifer*, and the Tethyan-type representatives are *Leptodus*, *Spinomarginifera*, *Richthofenia*, *Meekella*, *Rhipidomella*, *Geyerella*, *Transennatia*, *Orthothetina*, *Tyloplecta*, *Permundaria*, *Urushenoidea* and *Permianella*.

In the Hida Gaien Belt, Central Japan, a brachiopod fauna of early Middle Permian age was revealed by Horikoshi et al. (1987) from the lower part of the Moribu Formation in the Moribu district. The Moribu fauna contains the Boreal elements, *Alispiriferella*, *Yakovlevia*, *Waagenoconcha*, *Rhombospirifer*, *Stenosisma*, *Canocrinella*, *Megousia* and *Neospirifer*, and the Tethyan elements, *Urushenoidea*, *Transennatia*, *Leptodus*, *Permundaria* and *Enteleles*. Recently a Middle Permian brachiopod fauna was described by Tazawa & Matsumoto (1998) from the lower part of the Oguradani

Formation in the Oguradani district, about 70 km SW of Moribu. The Oguradani fauna contains the Boreal elements *Stenosisma* and some Tethyan elements, *Leptodus*, *Transennatia* and *Meekella*. The Moribu and Oguradani faunas are closely related to those of the South Kitakami Belt, South Primorye, Northeast China and Inner Mongolia in generic and specific levels.

In Central Kyushu, Southwest Japan, a Middle Permian brachiopod fauna was described by Yanagida (1963) from the upper part of the Mizukoshi Formation. The Mizukoshi fauna contains the Boreal elements, *Neospirifer* and *Spiriferella*, but no Tethyan elements. The lacking of the Tethyan-type brachiopods in this fauna may be owing to the incomplete material.

Akiyoshi Terrane. A brachiopod fauna of late Middle Permian age has been known from the Tsunemori Formation in the Akiyoshi district, Southwest Japan (Mabuti 1937; Yanagida 1996). The Tsunemori fauna contains *Spiriferella*, *Alispiriferella*, *Stenosisma* and *Megousia* as the Boreal elements, and *Gemmellaroia*, *Leptodus*, *Enteleles*, *Goniarina* and *Tyloplecta* as the Tethyan elements. In his report of the Tsunemori fauna, Yanagida (1996: 315) mentioned that this fauna is related to that of the Yangtze Platform (South China). However, the Tsunemori fauna is clearly a mixed fauna of the Boreal and Tethyan elements, and similar to the Middle Permian fauna of the South Kitakami Terrane and also to those of South Primorye and Northeast China in generic composition.

Tethyan–North American mixed fauna

Mino Terrane. Recently, a Middle Permian brachiopod fauna was described by Tazawa & Shen (1997) from Hiyomo in the Mino Belt, Central Japan. The brachiopods were collected from a limestone block in the Jurassic melange, widely distributed in the Hiyomo district. The Hiyomo fauna contains some Tethyan elements such as *Eteletes*, *Compressoproductus* and *Eolytonia*, but lacks completely both the Boreal and Gondwanan elements. It is noteworthy that the Hiyomo fauna contains North American elements, *Glyptosteges*, *Cenorhynchia* and *Lepidospirifer*, and resembles the Middle Permian (Leonardian to lower Guadalupian) brachiopod fauna of West Texas in generic and specific levels. Moreover, the presence of a typical North American-type genus *Coscinophora* and a Tethyan-type genus *Pelichia* has been revealed by Tazawa (1997c) and Shen (pers. comm.), respectively, from the lower part (*Parafusulina* Zone) of the Akasaka Limestone in the Akasaka district, Mino Belt, Central Japan. Consequently, it is defined that the Middle Permian brachiopod fauna of the Mino Terrane is the Tethyan–North American mixed one without the Boreal and Gondwanan elements.

The Nabeyama fauna, described by Hayasaka (1933) from the lower part of the Nabeyama Limestone in the Kuzu district, Ashio Belt, Central Japan, contains some Tethyan type genera, *Eteletes*, *Meekella* and *Orthoethina*, but several of Boreal aspect are completely absent. This fauna requires re-study because the presence of the Northern American-type brachiopods is strongly expected.

MIDDLE PERMIAN BRACHIOPOD FAUNAL PROVINCES OF JAPAN

Based on brachiopods and other marine organisms the following four realms are recognised in the Middle Permian time: the Boreal, Tethyan, Gondwanan and Panthalassan Realms. Moreover, several transitional zones may be added in the boundary regions (see Shi et al. 1995: fig. 1). In this paper, however, only two faunal zones concerning the Japanese brachiopod faunas, the Inner Mongolian–Japanese Transition Zone and the Tropical Panthalassan Zone, are discussed and shown on Fig. 2.

The Inner Mongolian–Japanese Transition Zone (Tazawa 1991) occupies the area of eastern sea of the Sino-Korean block and the boundary region

of the Boreal–Tethyan–Panthalassan realms of the Northern Hemisphere in the Middle Permian time. This transitional zone is characterised by the presence of both Boreal and Tethyan elements, and is represented by the faunas of the South Kitakami and Akiyoshi Terranes in Japan, South Primorye, Northeast China and Inner Mongolia.

The Tropical Panthalassan Zone, newly proposed in this paper, occupies the low latitude and mid regions between the Tethyan sea and North American continent. This zone is characterised by a very distinctive Tethyan–North American mixed fauna, and represented by some faunas from the exotic limestone blocks of the Mino Terrane, Japan.

MIDDLE PERMIAN RECONSTRUCTION OF JAPAN

The Middle Permian reconstruction of Japan is summarised as follows and shown on Fig. 2 and Table 1.

The Middle Permian of the South Kitakami Terrane, including the South Kitakami and Hida Gaien Belts, is composed of shallow-sea continental shelf deposits (Tazawa 1988, 1989), and can be correlated with those of South Primorye, Northeast China and Inner Mongolia in both lithostratigraphy and fossil contents (Tazawa 1996, 1997a). The Middle Permian brachiopod faunas of the South Kitakami Terrane are characterised by the mixed fauna of the Boreal and Tethyan elements (Tazawa 1987a, 1991, 1992; Nakamura & Tazawa 1990), and are closely related to those of South Primorye, Northeast China and Inner Mongolia. From the above data the Middle Permian reconstruction of these regions is considered to be the continental shelf bordering the eastern margin of the Sino-Korean block, which was present at a middle northern palaeolatitude and near the boundaries of the Boreal–Tethyan–Panthalassan realms.

The late Middle Permian Tsunemori Formation in the Akiyoshi Terrane is composed of deep-sea, trench-fill deposits (Kanmera 1983; Kanmera & Sano 1986), contrasting to those of the South Kitakami Terrane. But the brachiopod fauna from the Tsunemori Formation contains both the Boreal and Tethyan elements, similar to those of the South Kitakami Terrane and also to those of South Primorye, Northeast China and Inner Mongolia. These data suggest that the trench accumulating the sediments of the Tsunemori Formation was located at the front of eastern margin of the Sino-Korean block in the Middle Permian time.

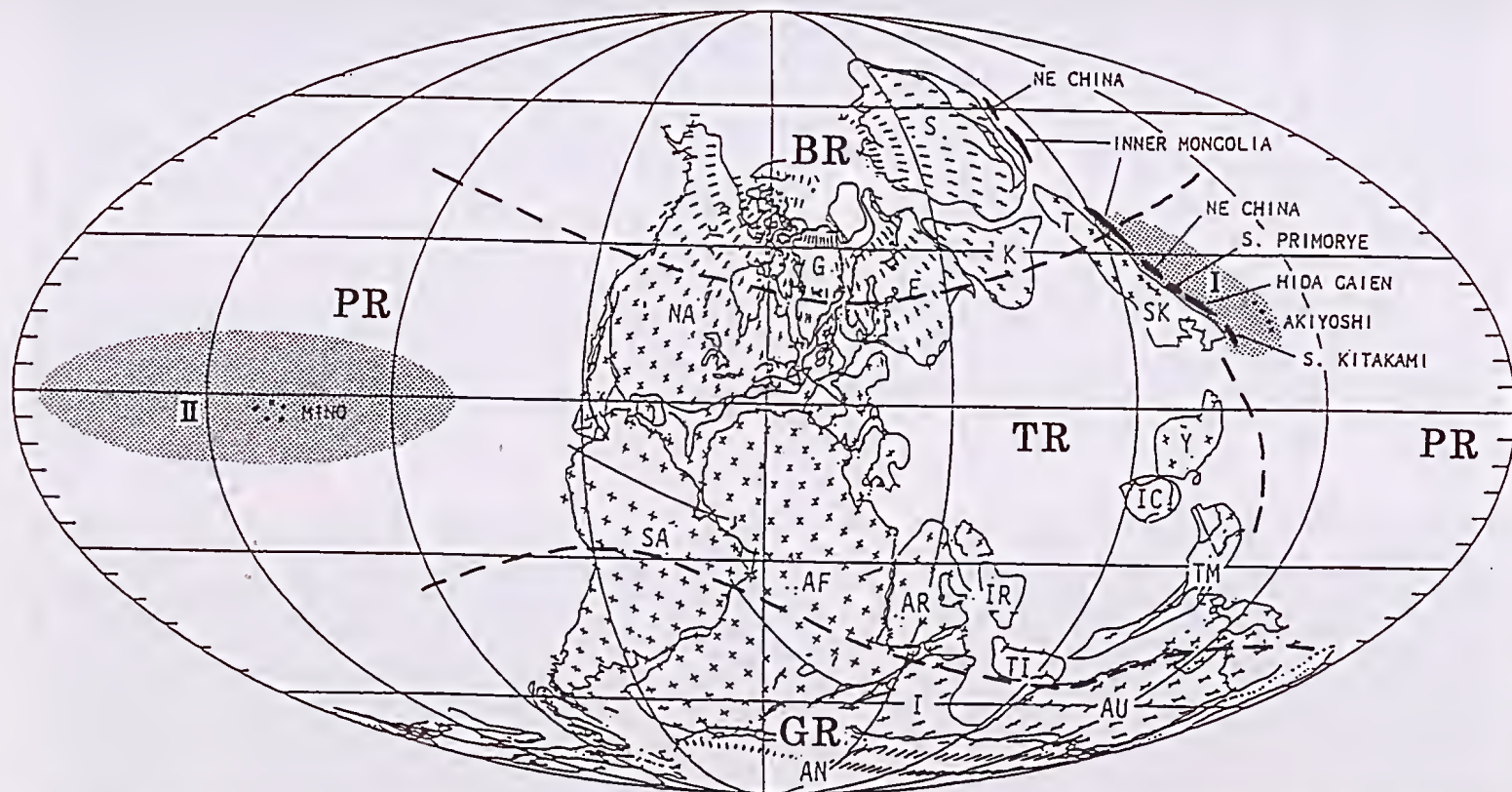


Fig. 2. Geographical and biogeographical reconstruction of Japan and its environs in the Middle Permian time (adapted and modified from Scotese & McKerrrow 1990; Tazawa 1992). Black areas are continental shelf or reef-seamount complex. Faunal province: I, Inner Mongolian-Japanese Transition Zone; II, Tropical Panthalassan Zone; BR, Boreal Realm; GR, Gondwanan Realm; PR, Panthalassan Realm; TR, Tethyan Realm. Continent or block: AF, Africa; AN, Antarctica; AR, Arabia; AU, Australia; E, Europe; G, Greenland; I, India; IC, Indochina; IR, Iran; K, Kazakhstan; NA, North America; S, Siberia; SA, South America; SK, Sino-Korea; T, Tarim; TI, Tibet; TM, Thai-Malaya; Y, Yangtze.

The Middle Permian brachiopods of the Mino Terrane are collected from the exotic limestone blocks in the Jurassic melange. The limestones often occur together with greenstones (basaltic rocks). From the palaeomagnetic (Hattori & Hirooka 1977, 1979), sedimentological (Sano 1988; Sano & Kanmera 1996) and palaeobiogeographical (Ishii et al. 1985; Ozawa 1987; Tazawa 1991, 1992) studies, the limestone-greenstone blocks are considered to have originated from the reef-seamount complexes situated at the equatorial region of the Panthalassa in the Permian time. But there was no information about the palaeolongitude of the region. Now, I have some data based on the brachiopod faunas, which are of mixed composition of the Tethyan-North American elements and shows the mid region between the Tethys and North America. From the above data, the Middle Permian reconstruction of the limestone-greenstone blocks of the Mino Terrane can be explained as discussed by Tazawa (1997b), the reef-seamount complexes on the mid-equatorial region of the Panthalassa, i.e. the Tropical Panthalassan Zone.

ACKNOWLEDGEMENTS

I thank Prof. N. W. Archbold and Dr G. R. Shi, School of Aquatic Science and Natural Resources Management, Deakin University, Clayton, Australia, for reading the manuscript.

REFERENCES

- BAMBACH, R. K., 1990. Late Palaeozoic provinciality in the marine realm. In *Palaeozoic palaeogeography and biogeography*, W. S. McKerron & C. R. Scotese, eds, The Geological Society Memoir, No. 12, The Geological Society Publishing House, Bath, 307-323.
- CHALONER, W. G. & CREBER, G. T., 1988. Fossil plants as indicators of late Palaeozoic plate positions. In *Gondwana and Tethys*, M. G. Andley-Charles & A. Hallam, eds, Geological Society Special Publication, No. 37, Oxford University Press, New York, 201-210.
- GRUNT, T. A., 1995. Biogeography of Permian basins. *Paleontologicheskii Zhurnal*, No. 4, 1995: 10-25. (In Russian.)
- GRUNT, T. A. & SHI, G. R., 1997. A hierarchical framework of Permian global marine biogeography. In *Palaeontology and Historical Geology*, Y. Jin & D. Dineley, eds, Proceedings of the 30th International Geological Congress, Vol. 12. VSP, Utrecht, 2-17.
- HATTORI, I. & HIROOKA, K., 1977. Paleomagnetic study of the greenstone in the Mugi-Kamiaso area, Gifu Prefecture, Central Japan. *Journal of the Japanese Association of Mineralogists, Petrologists and Economic Geologists* 72: 340-353.
- HATTORI, I. & HIROOKA, K., 1979. Paleomagnetic results from Permian greenstones in Central Japan and their geologic significance. *Tectonophysics* 57: 211-235.
- HAYASAKA, I., 1922. Some Permian brachiopods from the Kitakami Mountains. *Japanese Journal of Geology and Geography* 1: 51-70.
- HAYASAKA, I., 1925. On some brachiopods from the Lytonia horizon of the Kitakami Mountains. *Japanese Journal of Geology and Geography* 4: 89-103.
- HAYASAKA, I., 1933. On the Carboniferous brachiopod fauna from the Nabeyama region, Totigi Prefecture, Japan. *Memoir of the Faculty of Science and Agriculture, Taihoku Imperial University, Formosa, Japan* 6: 9-44.
- HAYASAKA, I., 1960. On the occurrence of *Neospirifer fasciger* (Keyserling) in Japan, and a note on some associate Permian brachiopods from around Kesen-numa City, Northeast Japan. *Collections of Essays in Commemoration of the Tenth Anniversary of Shimane University, Natural Science*, 34-57.
- HAYASAKA, I. & MINATO, M., 1956. Some brachiopods from the Lower Kanokura Series of the Kitakami Mountains, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, No. 21: 141-147.
- HORIKOSHI, E., TAZAWA, J., NAITO, N. & KANEDA, J., 1987. Permian brachiopods from Moribu, north of Takayama City, Hida Mountains, Central Japan. *Journal of the Geological Society of Japan* 93: 141-143. (In Japanese.)
- ISHII, K., OKIMURA, Y. & ICHIKAWA, K., 1985. Notes on Tethys biogeography with reference to Middle Permian fusulinaceans. In *The Tethys: Her paleogeography and paleobiogeography from Paleozoic to Mesozoic*, K. Nakazawa & J. M. Dickens, eds, Tokai University Press, Tokyo, 139-155.
- ISOZAKI, Y. & ITAYA, T., 1991. Pre-Jurassic klippe in northern Chichibu Belt in west-central Shikoku, Southwest Japan—Kurosegawa Terrane as tectonic outlier of the pre-Jurassic rocks of the Inner Zone. *Journal of the Geological Society of Japan* 97: 431-450. (In Japanese.)
- JIN, Y. & SHANG, Q., 1997. Palaeobiogeographic evolution of Permian brachiopods. In *Palaeontology and Historical Geology*, Y. Jin & D. Dineley, eds, Proceedings of the 30th International Geological Congress, Vol. 12. VSP, Utrecht, 29-53.
- KANMERA, K., 1983. A problem on the sedimentation and tectonics of the Upper Paleozoic rocks in Southwest Japan—accretion of allochthonous sedimentary bodies. In *Geologic development of the Kyushu Island*, T. Shuto, A. Aihara, T. Sakai & H. Sano, eds, Special Publication, Committee of Nishinohon Branch of the Geological Society of Japan, 67-76. (In Japanese.)

- KANMERA, K. & SANO, H., 1986. Stratigraphic and structural relationships among pre-Jurassic accretionary and collisional systems in Akiyoshi Terrane. In *Guidebook for Excursion*, Organising Committee of the International Symposium on pre-Jurassic East Asia, ed., IGCP Project 224, Osaka, 51–88.
- KOIZUMI, H., 1979. Permian brachiopods from Takakura-yama Formation and its geological age, N.E. Japan. *Bulletin of the Taira Chigaku Dokokai*, Spec. Vol. 1–3. (In Japanese.)
- KOMATSU, M., UJIHARA, M. & CHIHARA, K., 1985. Pre-Tertiary basement structure in the Inner Zone of Honshu and the North Fossa Magna region. *Contributions from the Department of Geology and Mineralogy, Niigata University* 5: 133–148. (In Japanese.)
- MABUTI, S., 1935. Stratigraphy of the Iwaizaki Limestone. *Saito Ho-on Kai Jiho*, No. 101: 1–18. (In Japanese.)
- MABUTI, S., 1937. On a Permian Brachiopoda, *Gemmellarioia (Gemmellarioiella) ozawai*, subgen. et sp. nov., from Japan. *Proceedings of the Imperial Academy of Tokyo* 13: 16–19.
- MINATO, M., HUNAHASHI, M., WATANABE, J. & KATO, M., 1979. *Variscan geohistory of northern Japan: The Abean Orogeny*. Tokai University Press, Tokyo, xiii + 427 pp.
- NAKAMURA, K., 1959. *Spinomarginifera* found in Japanese Permian. *Transactions and Proceedings of the Palaeontological Society of Japan*, New Series, No. 35: 143–146.
- NAKAMURA, K., 1960. *Dictyoclostus* derived from the Middle Permian Kanokura Series and the Lower Permian Sakamotozawa Series of the Kitakami Mountains, Japan. *Journal of the Faculty of Science, Hokkaido University*, Ser. 4, 10: 495–511.
- NAKAMURA, K., 1970. *Isogramma* from the Permian Kanokura Series of the Kitakami Mountains, Japan. *Journal of the Faculty of Science, Hokkaido University*, Ser. 4, 14: 301–311.
- NAKAMURA, K., 1972a. Permian Davidsoniacea from the Southern Kitakami Mountains, Japan. *Journal of the Faculty of Science, Hokkaido University*, Ser. 4, 15: 361–425.
- NAKAMURA, K., 1972b. *Anidantlus* and *Megousia* (Brachiopoda) from the Permian of Japan and Cambodia. *Journal of the Faculty of Science, Hokkaido University*, Ser. 4, 15: 427–445.
- NAKAMURA, K., 1979. Additional occurrences of *Urushitenoidea* (Brachiopoda) from the Permian of Asia. *Journal of the Faculty of Science, Hokkaido University*, Ser. 4, 19: 221–233.
- NAKAMURA, K., KATO, M. & CHOI, D. R., 1970. On *Permundaria*, a new genus of the brachiopod family Linoproductidae. *Journal of the Faculty of Science, Hokkaido University*, Ser. 4, 14: 293–299.
- NAKAMURA, K. & TAZAWA, J., 1990. Faunal provinciality of the Permian brachiopods in Japan. In *Pre-Jurassic terranes of Japan*, K. Ichikawa, S. Mizutani, I. Hara, S. Hada & A. Yao, eds, Publication of IGCP Project 224, Nippon Insatsu Shuppan, Osaka, 313–320.
- OTOFUJI, Y. & MATSUDA, T., 1983. Paleomagnetic evidence for the clockwise rotation of Southwest Japan. *Earth and Planetary Science Letters* 62: 349–359.
- OTOFUJI, Y., MATSUDA, T. & NOHOA, S., 1985. Paleomagnetic evidence for the Miocene counter-clockwise rotation of Northeast Japan: Rifting process of the Japan arc. *Earth and Planetary Science Letters* 75: 265–277.
- OZAWA, T., 1987. Permian fusulinacean biogeographic provinces in Asia and their tectonic implications. In *Historical biogeography and plate tectonic evolution of Japan and eastern Asia*, A. Taira & M. Tashiro, eds, Terra Scientific Publishing Company, Tokyo, 45–63.
- ROSS, J. R. P. & ROSS, C. A., 1990. Late Palaeozoic bryozoan biogeography. In *Palaeozoic palaeogeography and biogeography*, W. S. McKerrrow & C. R. Scotese, eds, The Geological Society Memoir, No. 12, The Geological Society Publishing House, Bath, 353–362.
- SANO, H., 1988. Permian oceanic-rocks of Mino Terrane, Central Japan, Pt 2. Limestone facies. *Journal of the Geological Society of Japan* 94: 963–976.
- SANO, H. & KANMERA, K., 1996. Microbial controls on Panthalassan Carboniferous–Permian oceanic buildups, Japan. *Facies* 34: 239–256.
- SCOTESE, C. R. & MCKERROW, W. S., eds, 1990. Revised world maps and introduction. In *Palaeozoic palaeogeography and biogeography*, The Geological Society Memoir, No. 12, The Geological Society Publishing House, Bath, 1–21.
- SHANG, Q. & JIN, Y., 1997. Quantitative evaluation on paleozoogeographic evidences of Permian brachiopods. *Acta Palaeontologica Sinica* 36: 93–121. (In Chinese.)
- SHEN, S. & TAZAWA, J., 1997. Two permianellids (Brachiopoda) from the Middle Permian of the Southern Kitakami Mountains, Northeast Japan. *Paleontological Research* 1: 285–290.
- SHI, G. R., ARCHBOLD, N. W. & ZHAN, L. P., 1995. Distribution and characteristics of mixed (transitional) mid-Permian (Late Artinskian–Ufimian) marine faunas in Asia and their palaeogeographical implications. *Palaeogeography, Palaeoclimatology, Palaeoecology* 114: 241–271.
- TAIRA, A., TOKUYAMA, H. & SOH, W., 1989. Accretion tectonics and evolution of Japan. In *The evolution of the Pacific Ocean margins*, Z. Ben-Avraham, ed., Oxford Monographs on Geology and Geophysics, No. 8, Oxford University Press, New York, 100–123.
- TAZAWA, J., 1974. *Waagenoconcha* (Brachiopoda) from the Permian of the Southern Kitakami Mountains, Northeast Japan. *Journal of the Faculty of Science, Hokkaido University*, Ser. 4, 16: 121–143.
- TAZAWA, J., 1976. The Permian of Kesennuina, Kitakami Mountains: A preliminary report. *Earth Science (Chikyu Kagaku)* 30: 175–185.

- TAZAWA, J., 1979. Middle Permian brachiopods from Matsukawa, Kesennuma region, Southern Kitakami Mountains. *Saito Ho-on Kai Museum Research Bulletin*, No. 47: 23–35.
- TAZAWA, J., 1987a. Permian brachiopod faunas of Japan and their palaeobiogeography. *Chikyū Monthly (Gekkan Chikyū)* 9: 252–255. (In Japanese.)
- TAZAWA, J., 1987b. Report of the fossils from the Kamiyasse district. *Report of the Cultural Assets, Kesennuma City, Miyagi Prefecture* 6: 1–37. (In Japanese.)
- TAZAWA, J., 1988. Palaeozoic–Mesozoic stratigraphy and tectonics of the Kitakami Mountains, Northeast Japan. *Earth Science (Chikyū Kagaku)* 42: 165–178. (In Japanese.)
- TAZAWA, J., 1989. Comparison between the Palaeozoic formations of the Southern Kitakami Mountains, NE Japan, and the Hida Marginal Belt, SW Japan: A preliminary note. *Earth Science (Chikyū Kagaku)* 43: 224–230. (In Japanese.)
- TAZAWA, J., 1991. Middle Permian brachiopod biogeography of Japan and adjacent regions in East Asia. In *Pre-Jurassic geology of Inner Mongolia, China: Report of China–Japan Cooperative Research Group, 1987–1989*, K. Ishii, X. Liu, K. Iehikawa & B. Huang, eds, Matsuya Insatsu, Osaka, 213–230.
- TAZAWA, J., 1992. Middle Permian brachiopod faunas in East Asia and their zoogeographic significance. *Journal of the Geological Society of Japan* 98: 483–496. (In Japanese.)
- TAZAWA, J., 1993. Pre-Neogene tectonics of the Japanese Islands from the viewpoint of palaeobiogeography. *Journal of the Geological Society of Japan* 99: 525–543. (In Japanese.)
- TAZAWA, J., 1996. The Permian continental shelf deposits in the Kitakami, Hida and Sikhote-Alin Mountains and their correlation. *Chikyū Monthly (Gekkan Chikyū)* 18: 387–392. (In Japanese.)
- TAZAWA, J., 1997a. The Permian System of Northeast China and Inner Mongolia: Comparison with the Permian of the South Kitakami and Hida Gaien Belts, Japan. *Annual Report of the Institute of Industrial Sciences*, No. 8: 135–145. (In Japanese.)
- TAZAWA, J., 1997b. Permian brachiopods from Hiyomo, east of Takayama, Central Japan: A palaeobiogeographical data on the origin of limestone–greenstone blocks in the Mino Belt. *Journal of the Geological Society of Japan* 103: 908–911. (In Japanese.)
- TAZAWA, J., 1997c. *Coscinophora* (Permian Brachiopoda) from the Akasaka Limestone, Mino Belt, Central Japan and its palaeobiogeographical significance. *Earth Science (Chikyū Kagaku)* 51: 447–451. (In Japanese.)
- TAZAWA, J. & ARAKI, H., 1984. A new species of *Richthofenia* (Brachiopoda) from the Permian of Northeast Japan. *Saito Ho-on Kai Museum Research Bulletin*, No. 52: 1–7.
- TAZAWA, J. & GUNJI, Y., 1982. Middle Permian brachiopods from the Oashi Formation, Abukuma Mountains, Northeast Japan. *Saito Ho-on Kai Museum, Natural History, Research Bulletin*, No. 50: 67–74.
- TAZAWA, J. & MATSUMOTO, T., 1998. Middle Permian brachiopods from the Oguradani Formation, Ise district, Hida Gaien Belt, Central Japan. *Science Reports of Niigata University*, Ser. E, No. 13: 1–19.
- TAZAWA, J. & SHEN, S., 1997. Middle Permian brachiopods from Hiyomo, Mino Belt, Central Japan: Their provincial relationships with North America. *Science Reports of Niigata University*, Ser. E, No. 12: 1–17.
- XU, G. & YANG, W., 1988. Chapter 10. Permian. In *Paleobiogeography of China*, H. Yin et al., eds, China University of Geosciences Press, Wuhan, 176–197. (In Chinese.)
- XU, G. & YANG, W., 1994. Chapter 8. Permian. In *The palaeobiogeography of China*, H. Yin, ed., Oxford Biogeography Series, No. 8, Oxford University Press, New York, 163–188.
- YANAGIDA, J., 1963. Brachiopods from the Upper Permian Mizukoshi Formation, Central Kyushu. *Memoirs of the Faculty of Science, Kyushu University*, Ser. D, 14: 69–78.
- YANAGIDA, J., 1996. Permian brachiopods from the Tsunemori Formation, SW Japan, and their palaeobiogeographic implication. In *Brachiopods*, P. Copper & J. Jin, eds, Proceedings of the Third International Brachiopod Congress, Sudbury, Ontario, Canada, 2–5 September 1995. A. A. Balkema, Rotterdam, 313–315.
- YANAGISAWA, I., 1967. Geology and paleontology of the Takakurayama–Yaguki area, Ytotsukura-cho, Fukushima Prefecture. *Science Reports of the Tohoku University*, 2nd Series, 39: 63–112.
- ZIEGLER, A. M., 1990. Phytogeographic patterns and continental configurations during the Permian Period. In *Palaeozoic palaeogeography and biogeography*, W. S. McKerrow & C. R. Scotese, eds, The Geological Society Memoir, No. 12. The Geological Society Publishing House, Bath, 363–379.